What are the Safety Implications of Crown Fires?

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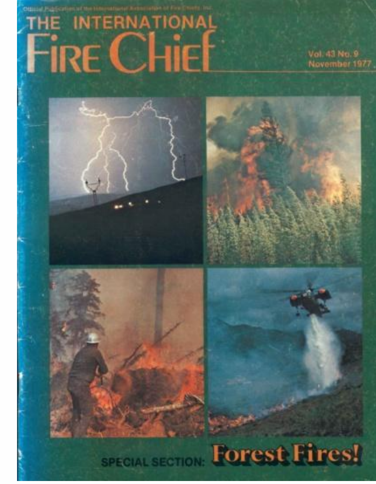
As for big fires in the early history of the Forest Service, a young ranger made himself famous by answering the big question on an exam, "What would you do to control a crown fire?" with the one-liner, "Get out of the way and pray like hell for rain."

Norman Maclean (1992)

Young Men & Fire

Crown Fire – *This is the most spectacular kind of forest fire. Since it is over the heads of ground forces it is uncontrollable until it again drops to the ground, and since it is usually fast-moving it poses grave danger to fire fighters and wildlife in its path. It is the most common cause of fire fighters becoming trapped and burned.*

Arthur A. Brown & Kenneth P. Davis (1973)
Forest Fire: Control and Use. 2nd Edition



Forest Fires!

Fatal and Near-Fatal Forest Fires The Common Denominators

by Carl C. Wilson

Fighting large forest fires often is compared to military operations. Each involves a highly structured organization with a "general" at the head, massive mov … actical aerial support and … ess until the enemy finall … e major difference betw … egy: in suppressing larg … lated risk of losing fire fi … nany people have lost the … States.

The conce … similarities between tho … nd those in which somec … s this article will show, th … ds on many factors, the … eing that of human beha …

A review … rds between 1926 and 19 … 1 fires from fire-induced … vy losses in recent years. The largest losses on single fires occurred on the Blackwater fire in Wyoming in 1937 and on the Rattlesnake fire in California in 1953 (Table 1). In each case, 15 people died. A similar analysis made of people lost on fires in areas protected by other Federal agencies and Stat…

2. Most of the fires were innocent in appearance prior to the "flare-ups" or "blow- ups". In some cases, the fatalities occurred in the mop-up stage.

3. Flare-ups occurred in deceptively light fuels.

4. Fires ran uphill in chimneys, gullies, or on steep slopes.

5. Suppression tools, such as helicopters or air tankers, can adversely modify fire behavior. (Helicopter and air tanker vortices have been known to cause flare-ups.)

In Tables 3 and 4, near-fatal fires are those close calls which involved a potential threat to life. A review of these tables shows that most of the generalizations made concerning fire behavior apply to near-fatal fires as well as to fatal fires. The hairline difference between the two groups of fires is determined by the individual's reaction to his suddenly critical situation. Escapes may be said to be due either to luck, circumstances, advance planning, a person's ability to stay cool and not panic, or a combination of these factors. Whatever the reasons, individual behavior and circumstances determine between life and death. For the individual fire fighter and crew boss, it becomes increasingly important to be able to identify those conditions under which so many close calls and fatalities occur.

Common Denominators of Fire Behavior on Tragedy Fires

1. Most incidents happen on **small fires** or on isolated sections of large fires.

2. Flare-ups generally occur in deceptively light fuels, such as **grass** and light brush.

3. Most fires are innocent in appearance before unexpected shifts in wind direction and/or speed result in “**flare-ups**.” Sometimes, tragedies occur in the mop-up stage.

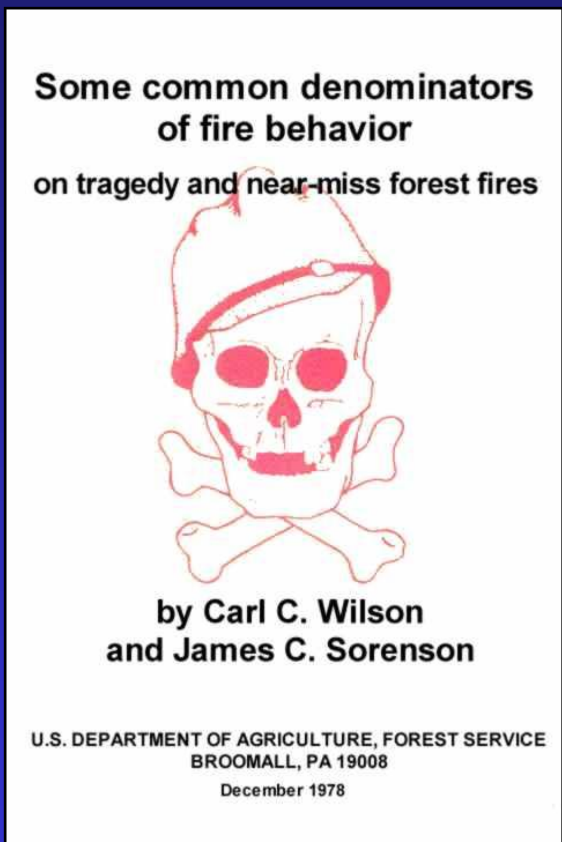
Continued…

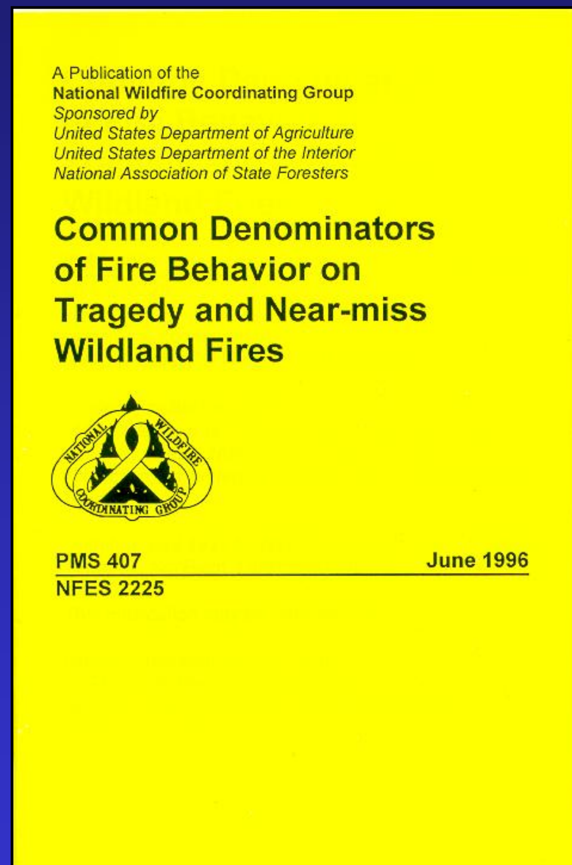
Common Denominators of Fire Behavior on Tragedy Fires

4. Fires respond to large and small-scale topographic conditions, running uphill surprisingly fast in chimneys, gullies, and on steep slopes

5. Helicopters or air tankers can adversely affect fire behavior in certain situations. The blasts of air from low-flying aircraft have been known to cause flare-ups.

Common Denominators of Fire Behavior on Tragedy and Near-miss Wildland Fires





Many firefighters are surprised to learn that tragedy and near-miss incidents occur in fairly light fuels, on small fires, or on isolated sectors of large fires, and that fire behavior is relatively quiet just before the incident. Most of us believe that the high-intensity crown fire in timber or heavy brush is what traps and kills forest firefighters. Yet, with rare exceptions ... most fires are innocent appearing just before the accidents.

Wilson and Sorenson (1978)

Incident Response Pocket Guide

PMS 461
NFES 1077
January 2010

Common Denominators of Fire Behavior on Tragedy Fires

There are four major common denominators of fire behavior on fatal and near-fatal fires. Such fires often occur:

1. On relatively small fires or deceptively quiet areas of large fires.

2. In relatively light fuels, such as grass, herbs, and light brush.

3. With unexpected shifts in wind direction or wind speed.

4. When fire responds to topographic conditions and runs uphill.

Alignment of topography and wind during the burning period should be considered a trigger point to reevaluate tactics.

Some Examples of Firefighter Fatalities Associated with “Timber” Crown Fires

- 1937 Blackwater Fire – Wyoming (15 fatalities)
- 1958 Wandilo Fire – South Australia (8 fatalities)
- 1967 Sundance Fire – Idaho (2 fatalities)
- 1977 Bass River Fire – New Jersey (4 fatalities)
- 1980 Mack Lake Fire – Michigan (1 fatality)
- 1990 Dude Fire – Arizona (6 fatalities)
- 1994 Sabie – South Africa (10 fatalities)
- 2001 Thirtymile Fire – Washington (4 fatalities)


Fire behavior is defined as the manner in which fuel ignites, flame develops, fire spreads and exhibits other related phenomena as determined by the fire environment.

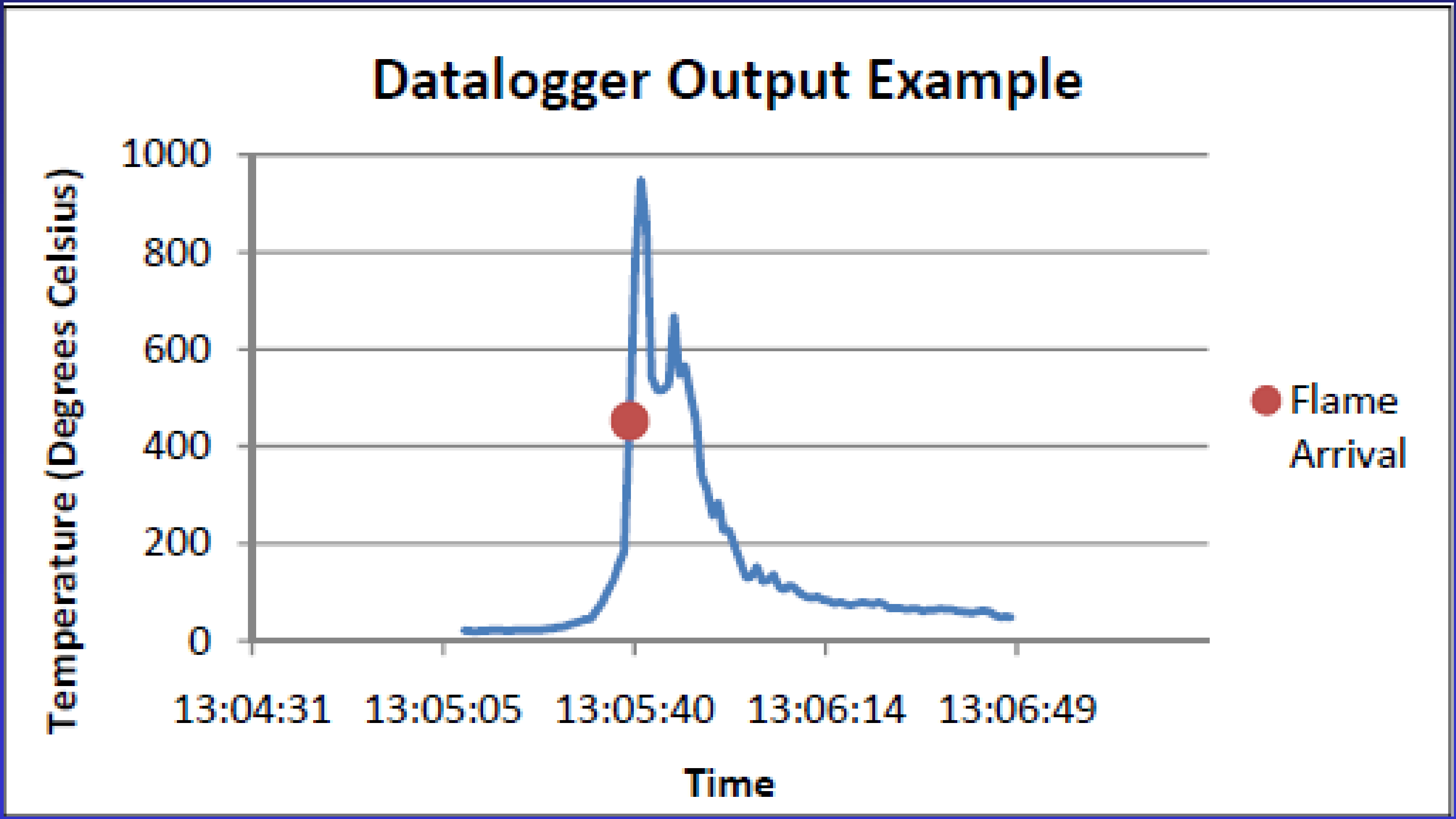
The more important fire behavior characteristics from the practical standpoint of fire suppression are:

- Forward Rate of Spread
- Fireline Intensity
- Flame Front Dimensions
- Spotting Pattern (densities & distances)

- Fire Size and Shape
- Rate of Perimeter Increase
- Burn-out Time

Thermal Environment of a Wildland Fire

Time-temperature trace recorded as a the moving flame front of grass fire passes by a given point



In-fire video from International Crown Fire Modelling Experiment

Fig 3. Crown fire progression beneath the canopy in plot 3 recorded over 2.5 min on June 28, 2000. The rate of spread is about 20–30 m·min^{-1} (0.35–0.5 m·s^{-1}). (A) 15:08:26, spot fire starts from ember rain about 10 m ahead of the flame front. (B) 15:08:40, vapo[r] release from bark on tree boles at about 6 m ahead of the flame front. (C) 15:08:48, ignition of forest floor patches and tree boles about 3–4 m ahead of the flame front. (D) 15:08:52, arrival of continuous flame front. (E) 15:09:02, flaming below canopy. (F) 15:10:57, residual flaming of forest floor, downed woody debris, and tree boles.

See "Inside the Fire"

http://www.youtube.com/

Contrasting Fire Behavior Potential: fuel type characteristics

Grass

Fuel load – 1.6 T/ac

Fuel height – 1 ft

Degree of curing – 100%

Conifer Forest

Surface fuel load – 5 T/ac

Stand height – 45 ft

Canopy base height – 20 ft

Canopy fuel load – 4.5 T/ac

Canopy bulk density – 0.14 lb/ft^3 (0.23 kg/m^3)

Contrasting Fire Behavior Potential: environmental conditions

Slope steepness: 0% (flat topography)

Air temperature: 86 deg F

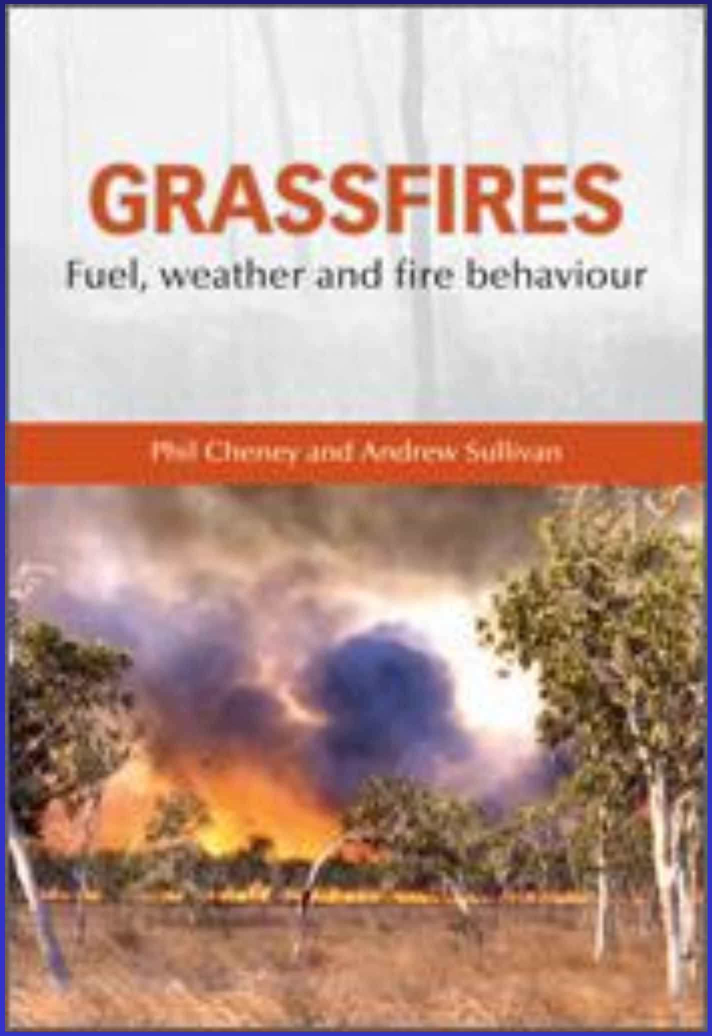
Relative humidity: 20%

Grass fuel moisture: 4.8%

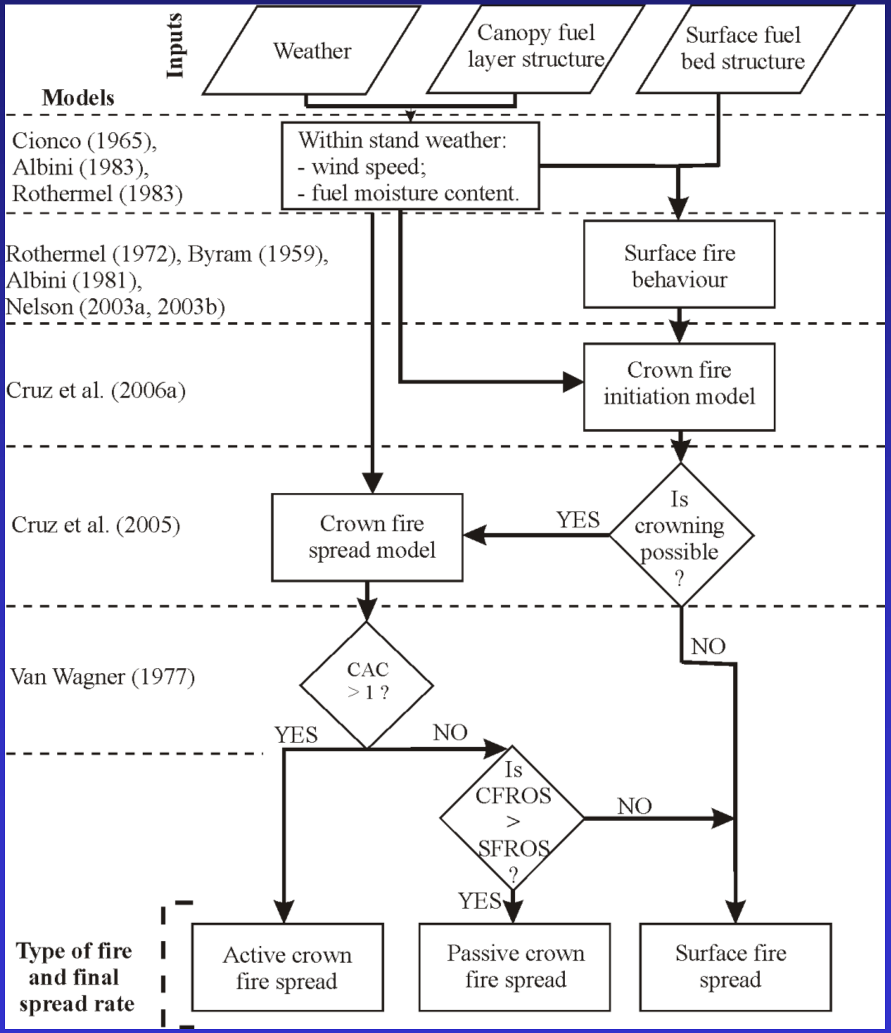
Conifer forest – surface fuel moisture: 6%

Contrasting Fire Behavior Potential: predictive models or systems

Australian Work

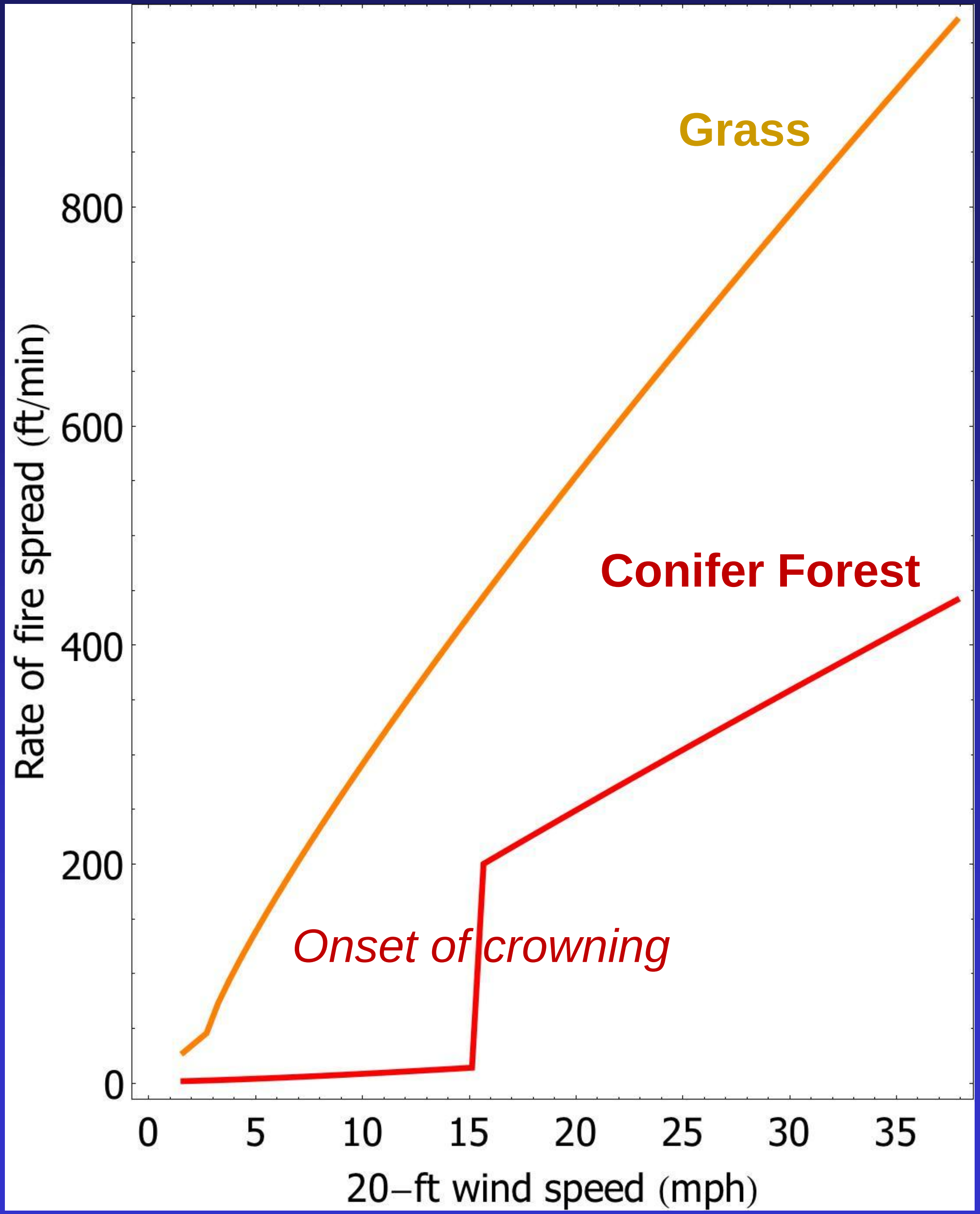


Cruz, Alexander & Fernandes (2008)



What distinguishes wildland fires from structural or urban fires is their horizontal spread potential.

Rate of Fire Spread vs. Wind Speed

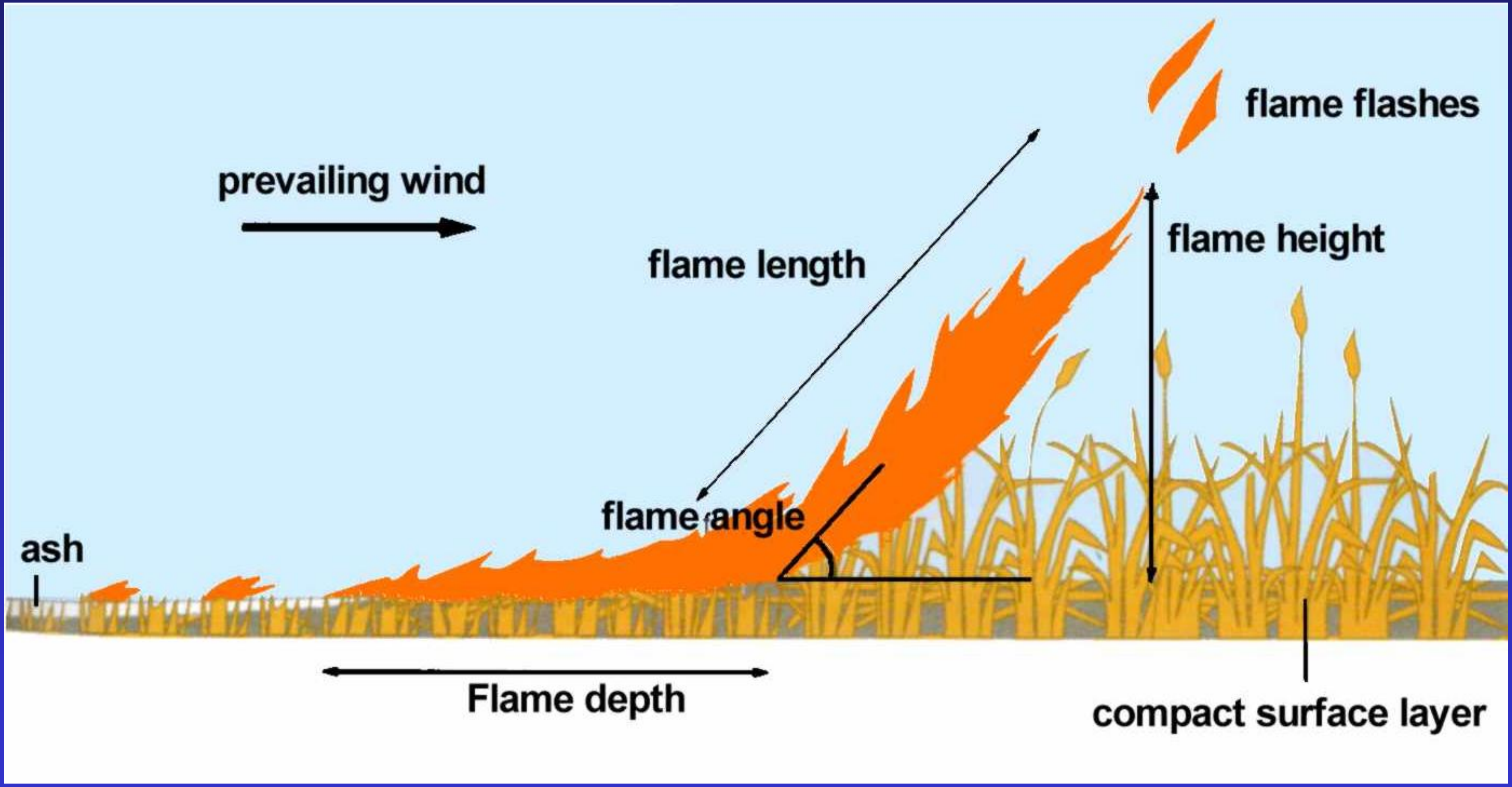


Fireline Intensity

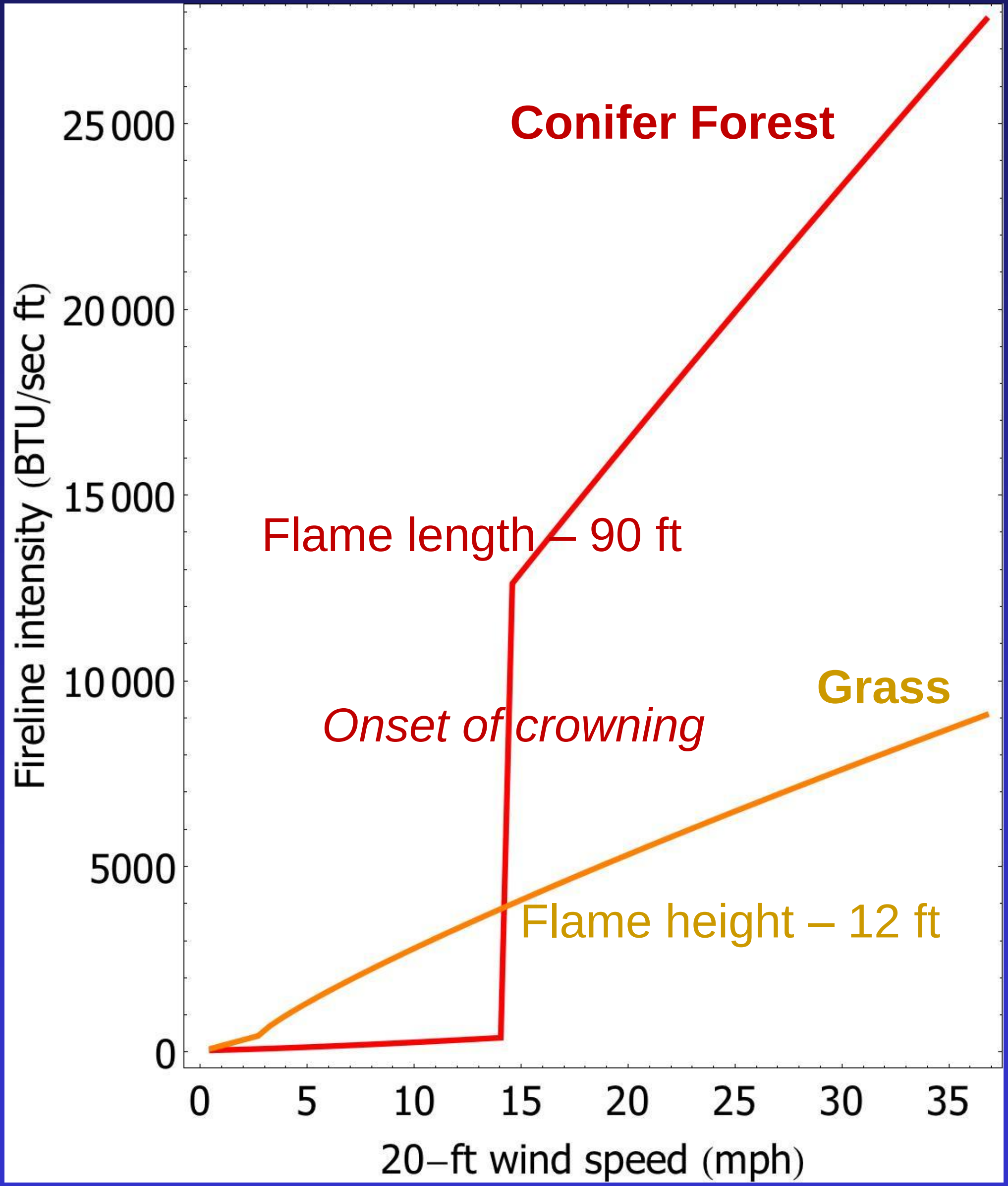
$$I \quad = \quad H \quad \times \quad W \quad \times \quad R$$

I	H	W	R
Fireline Intensity (Btu/sec-ft)	Heat of Combustion (Btu/lb)	Fuel Consumed (lb/ft^2)	Rate of Fire Spread (ft/sec)

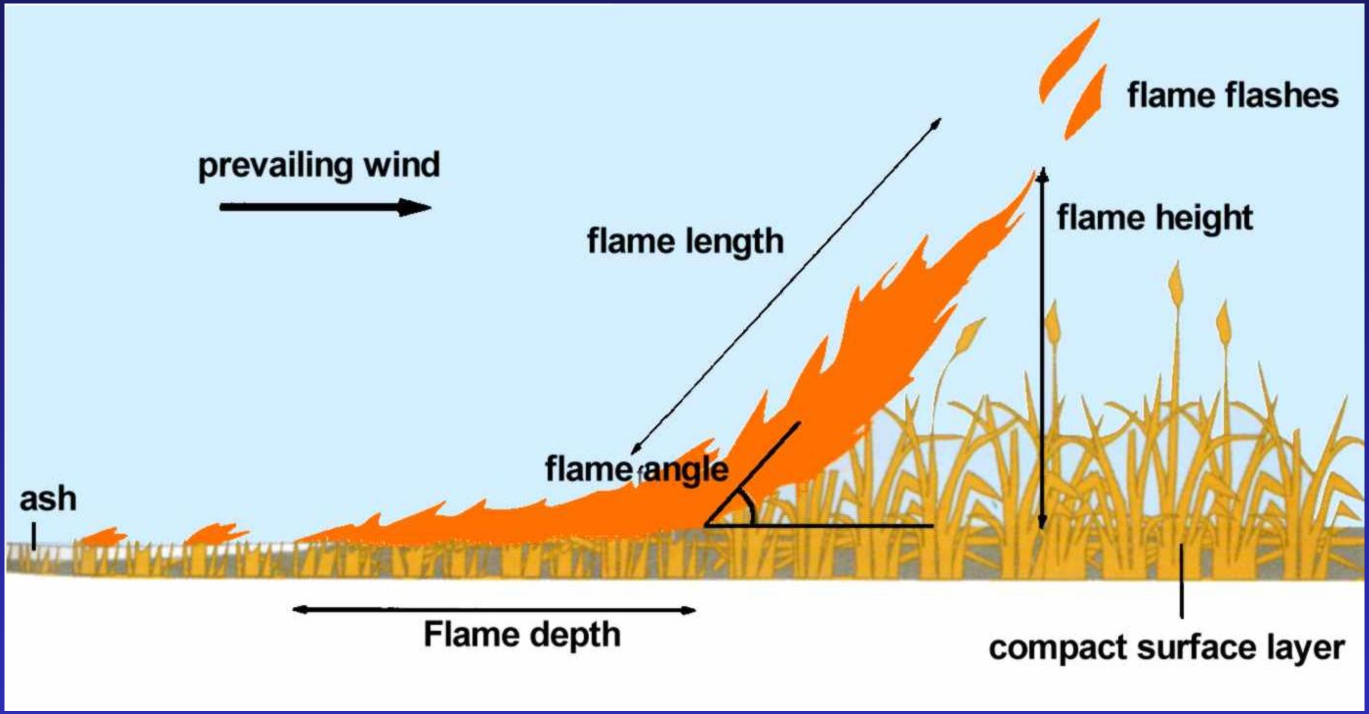
Fireline Intensity = 30 x (Flame Length)^2



Fireline Intensity vs. Wind Speed

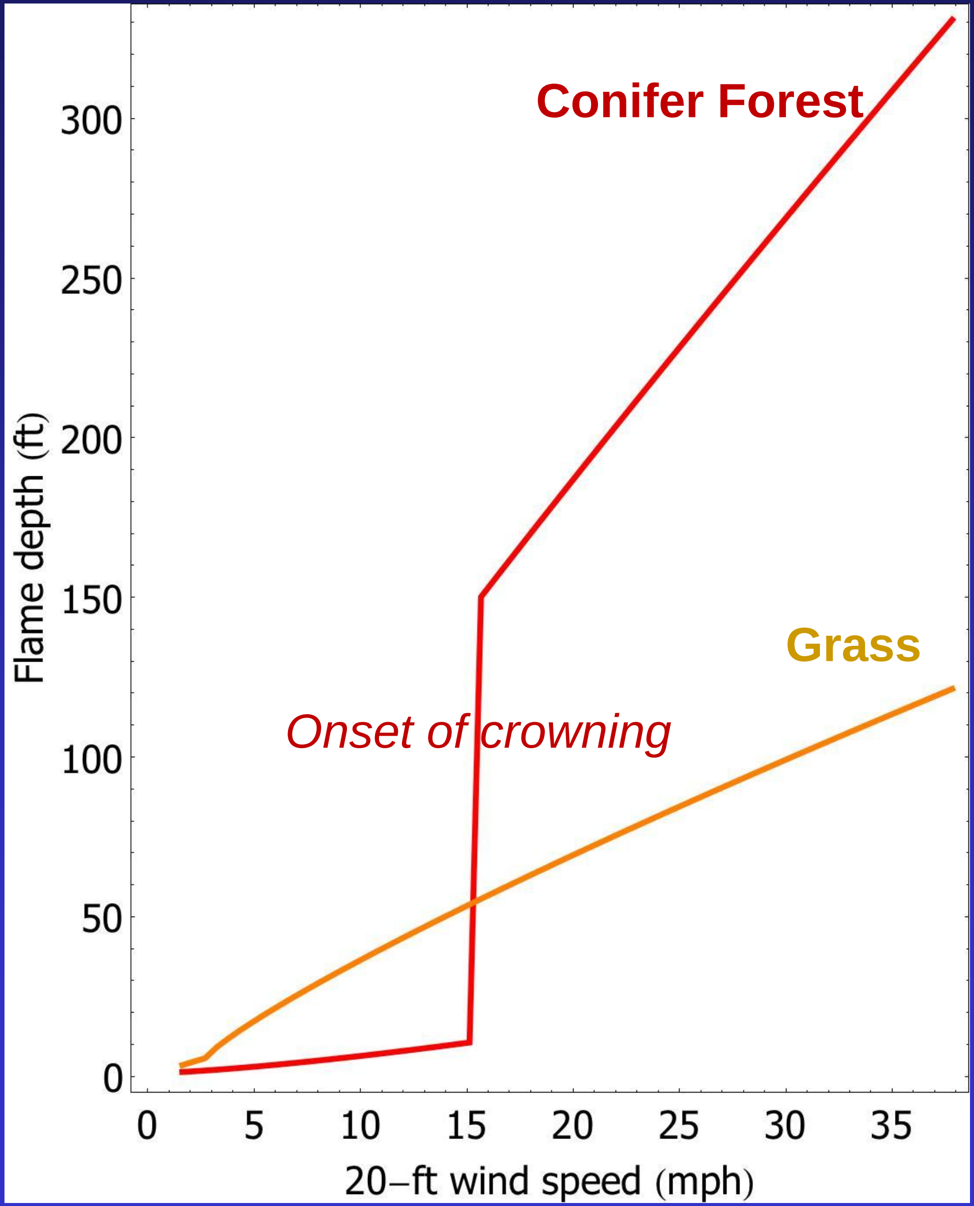


Flame Depth



Flame Depth =
Flame Front Residence Time x Rate of Fire Spread

Flame Depth vs. Wind Speed



Relative Fire Behavior Potential

Grass	Brush	Conifer Forest
		
	<u>Rate of Fire Spread</u>	
Highest	Intermediate	Lowest
	<u>Fireline Intensity</u>	
Lowest	Intermediate	Highest
	<u>Flame Length</u>	
Lowest	Intermediate	Highest
	<u>Flame Depth</u>	
Lowest	Intermediate	Highest

Relative Fire Behavior Potential

Grass	Brush	Conifer Forest
		
	Rate of Fire Spread	
Highest	Intermediate	Lowest
	Fireline Intensity	
Lowest	Intermediate	Highest
	Flame Length	
Lowest	Intermediate	Highest
	Flame Depth	
Lowest	Intermediate	Highest

Other Fire Behavior Characteristics

Grass	Brush	Conifer Forest
		
Flame Front Residence Time (seconds)		
5-10	10-20	30-60
Firewhirls		
Small	Moderate-sized	Large
Maximum Spotting Distances (miles)		
< 0.1	~4.0	~10
Maximum Burn-out or Smoulder Time (minutes)		
1	1-3	10-20

Some of the Major Differences

Grass fires are certainly far more responsive to the influence of wind than surface and crown fires in conifer forests which can easily lead to very sudden changes in the rate of spread <u>and</u> the direction of fire spread as a result of the natural variability in winds.

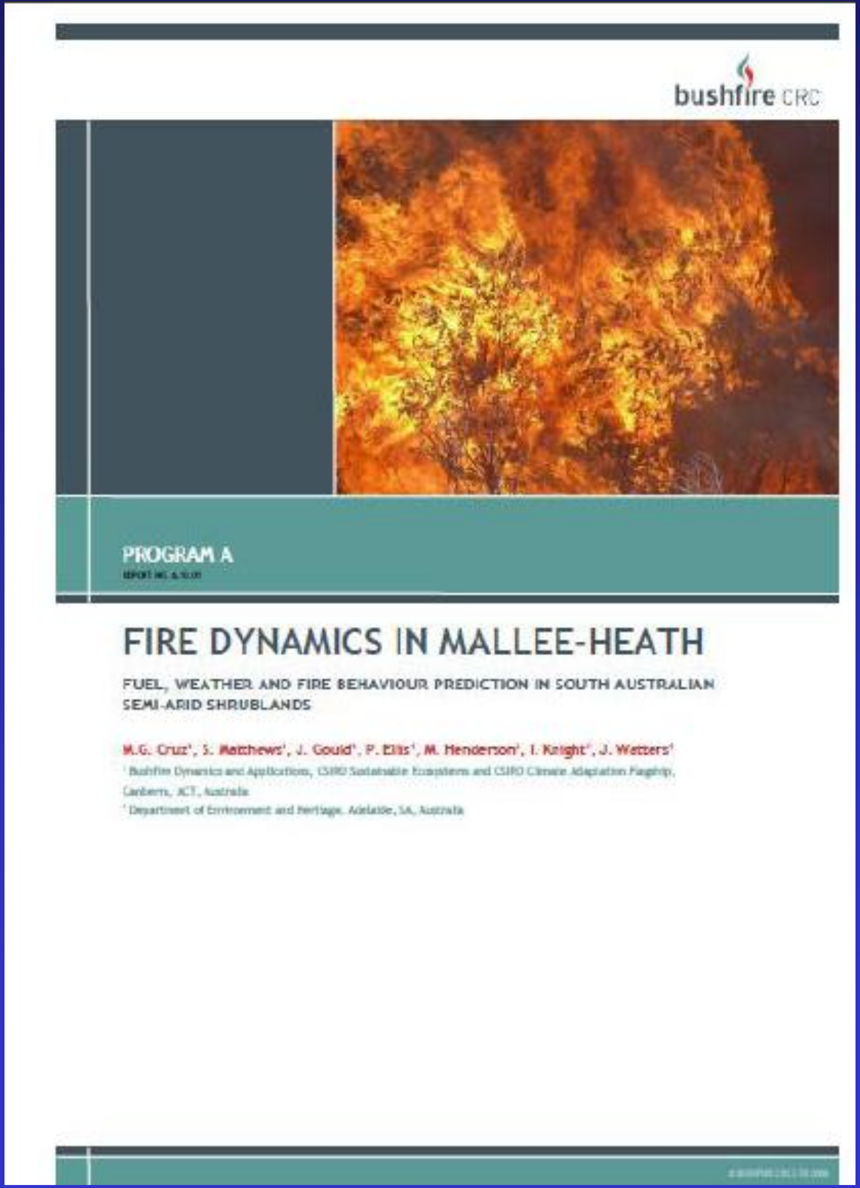
However, the heavy fuel loads associated with conifer forests easily lead to far more intense flame fronts than grass fires are capable of producing, thereby requiring larger safety zones for firefighters, especially for crown fires.

The Significance of the Surface Fire – to – Crown Fire Transition in Conifer Forests

If a conifer forest stand is capable of active crown fire propagation, the most obviously thing that occurs with the onset of crowning is the dramatic increase in flame height (and in turn the radiant heat flux) -- from perhaps 6 feet to 90+ feet in a span of a few seconds.

This abrupt change in fire behavior is not presently modeled by all predictive systems.

Recent fire research in Australian has identified similar patterns in shrubland fuel complexes



bushfire CRC

PROGRAM A

FIRE DYNAMICS IN MALLEE-HEATH

FUEL, WEATHER AND FIRE BEHAVIOUR PREDICTION IN SOUTH AUSTRALIAN SEMI-ARID SHRUBLANDS

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Department of Environment and Heritage, Adelaide, SA, Australia

Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC

bushfire CRC afac

FIRE NOTE

ISSUE 66 SEPTEMBER 2010

FIRE DYNAMICS IN MALLEE-HEATH

SUMMARY

This research focused on characterising fuel dynamics and fire behaviour characteristics in South Australian semi-arid mallee-heath fuels. An experimental burning program was carried out in the Ngarkat Conservation Park, SA, to develop the base data from which a new model system describing fire behaviour in mallee-heath fuels was developed. The system describes fire characteristics commonly required by fire managers in semi-arid environments, namely: fire sustainability (go/no-go thresholds), rate of fire spread, flame front characteristics, the onset and propagation of active crown fires and associated spotting activity. The models have particular relevance in planning and conducting prescribed fire operations, leading to a more effective and safe use of available resources.

ABOUT THIS FIRE NOTE

This is a summary of the research conducted as part of Project A1.1: Fire Behaviour Modelling, and is part of Bushfire CRC Program A: Safe Prevention, Preparation and Suppression.

The authors: Miguel Cruz (right) and Jim Gould, CSIRO Ecosystem Sciences and Climate Adaptation Flagship, Canberra.

CONTEXT

Knowledge of the fire behaviour potential associated with a specific fire scenario (fuels, weather, topography) is key to a variety of fire management actions. The accurate and comprehensive prediction of fire behaviour potential is critical for (1) improving assessment for bushfire hazards and risks; (2) supporting bushfire suppression tactics and strategies; (3) designing and comparing fuel treatments and outcomes; and (4) prioritising fuel treatment and response options.

BACKGROUND

Mallee-heath vegetation in semi-arid and Mediterranean climates develops a vertically non-uniform and spatially discontinuous fuel complex. The heterogeneity of the fuel layers sustaining fire propagation leads to fire behaviour characterised by nonlinear dynamics where small changes in the drivers of fire spread lead to large changes in observed fire behaviour. These sudden changes in fire spread and intensity are associated with the fire transitioning between different fuel strata (litter and near surface → elevated → overstorey) and the onset of fire dependent mechanisms such as spotting phenomena. As such, fire behaviour in mallee-heath fuels is not just a function of fuels and weather, but to a large extent determined by the interactions between those variables and the structure of the flame front. Current fire behaviour models available to fire managers do not incorporate these features, hence failing to adequately describe fire potential in mallee-heath fuel complexes. Furthermore, current models do not describe the fire characteristics necessary to understand the effects of fire on ecosystem components, limiting the linkages between fire behaviour components of a fire prescription and the expected impacts in soil, water, flora, fauna and air quality.

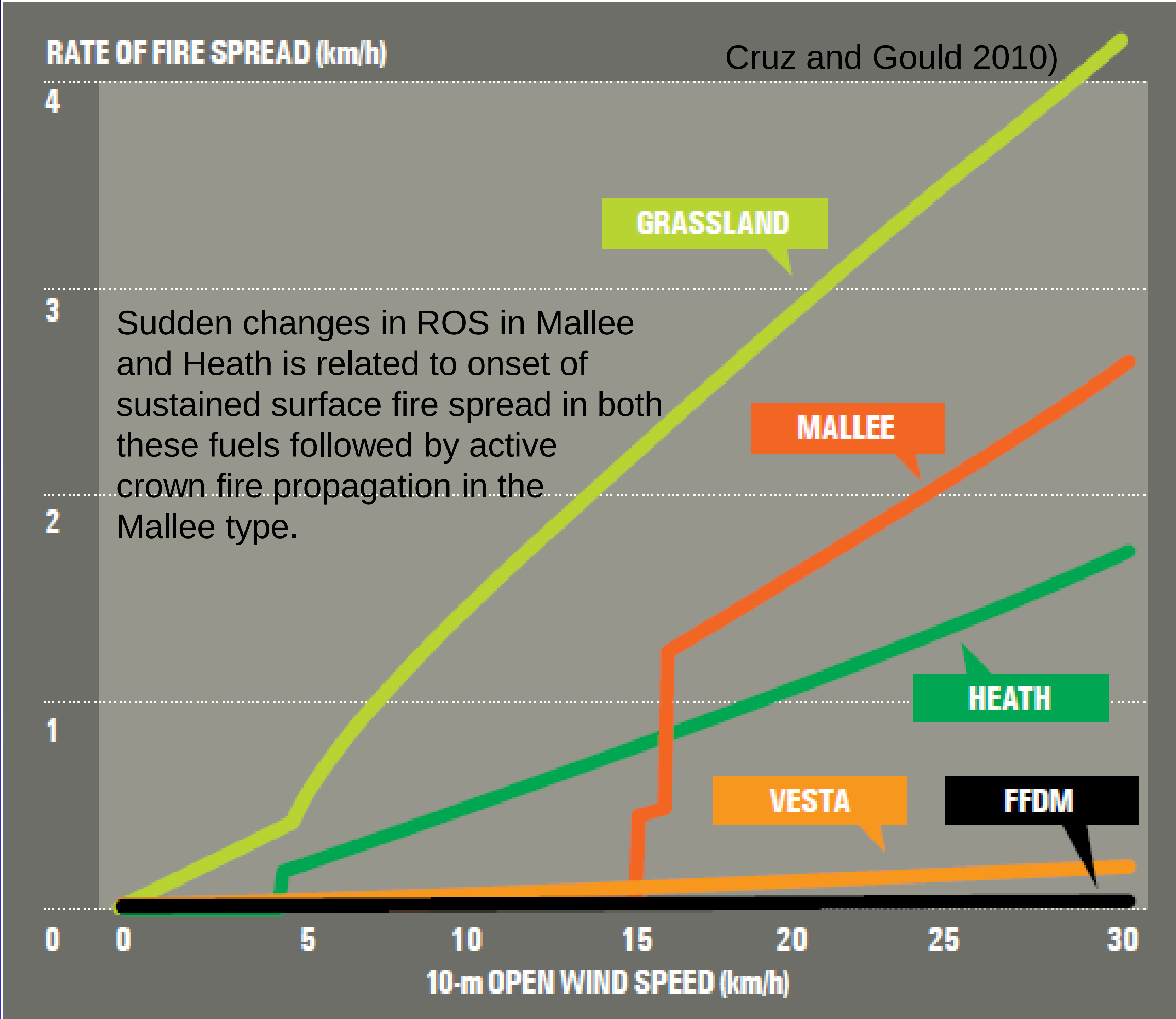
BUSHFIRE CRC RESEARCH

To develop a model system that would allow accurate predictions of prescribed fire behaviour in mallee-heath fuel complexes the study focused on four main research subjects:

- To quantify how fuel structures change with time since fire in mallee-heath

1

Cruz and Gould 2010)



Sudden changes in ROS in Mallee and Heath is related to onset of sustained surface fire spread in both these fuels followed by active crown fire propagation in the Mallee type.

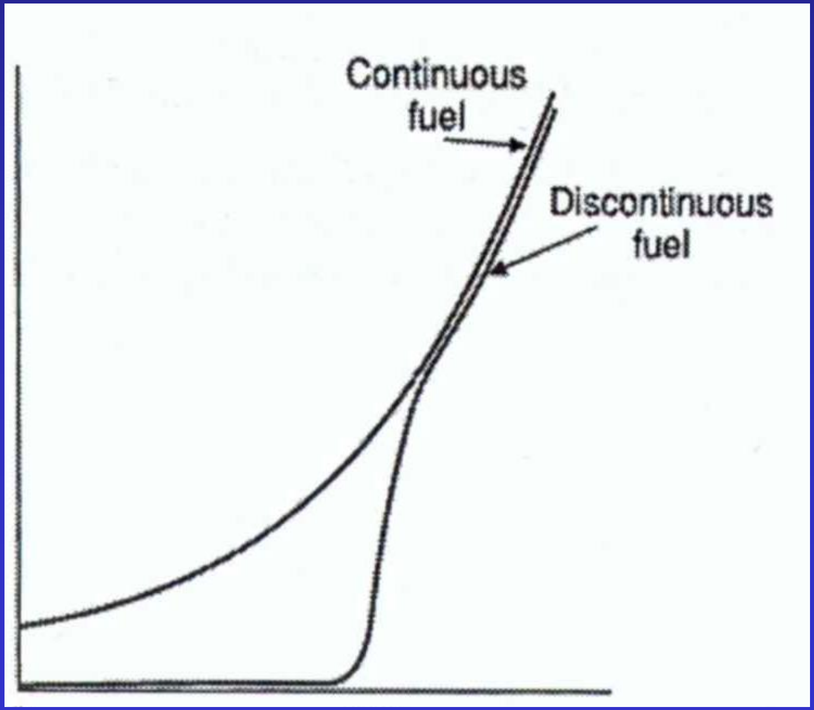
Key Take-home Message #1

We need to re-emphasize that there are many aspects or characteristics of wildland fire behavior and should strive to relate fire behavior more directly to fire suppression (e.g., fireline production rates, firefight travel rates) -- in other words, a more holistic approach.

Key Take-home Message #3

Provide scientific explanation for Wilson's common denominators in light of fire behavior research completed since 1977 and incorporate this information into fire behavior training.

Rate of Fire Spread



Wind Speed

Key Take-home Message #3

Look to incorporate the latest insights into the dynamics of wildland fire behavior into training and operations.